§24. Multiple Ionization and Recombination in the Gas Calibration of a Heavy Ion Beam Probe (HIBP) on JIPP T-IIU

Hamada, Y., Nishizawa, A. , Kawasumi, Y., Fujisawa, A., and Iguchi, H.

The calibration of a high-voltage HIBP through collisional ionization of the primary beam with neutral gas has some problems, since the cross-section of recombination is higher than that of ionization. Figure 1 shows time behaviours of the sum of the secondary beam currents, the difference of upper and lower detector currents normalized by those sum (ND) at 6 successive poloidal sweeps under gas puffing and a monitor signal of the poloidal sweep voltage in gas calibation experiment. The thallium beam energy is 450 keV and B_t = 3 Telsa. The repetition rate of the sweep is 500 Hz. The time for n-th sweep is subtracted by 2 x n ms to compare the behaviours of 6 successive sweeps in a more accurate way. Gas puffing lasts more than 50 ms. At later poloidal sweep, the sum signal is larger because the density of the gas in the vessel grows linearly in time during the gas puffing. As the sum increases, the small detector current begin to be observed at the range of the sweep voltage for the non-existence condition of the secondary beam to the analyzer slit. In contrast, at the range of hitting of the secondary beam on the lower part of the horizontal port, no change occurs as the density of neutral gas increases.

This can be considered as a clear evidence of the multiple process of the recombination and ionization. The cross-sections of the recombination, $Tl^+ + H_e = Tl + H_e^+$ and $Tl^{++} + H_e = Tl^+ + H_e^+$

are higher than those of the ionization process $Tl^+ + H_e = Tl^{++} + H_e + e$, and $Tl^{++} + H_e = Tl^{+++} + H_e + e$.

Since the analyzer detects the secondary beam, the main process of the multiple process is the addition of the recombination and subsequent ionization in the primary and secondary beam. We can see from Fig. 2 that the effect of the recombination and ionization tends to move the primary beam inwards i.e., towards the symmetry axis of the tokamak. This may be equivalent to the move to higher sweep voltage. In this case, at the region of wall hitting, the effect of multiple process can not be observed since the particle with multiple process hits the wall more easily. At the region outside the non-existence boundary, the particle with multiple process in the forbidden region is equivalent to the particle in the allowed band and the effect is observed.

Because the upper sample volume is far outside the plasma boundary in this case, the presence of the double sample volume does not cause serious trouble in the plasma potential measurement. As for the potential calibration by neutral gas however, the existence of double sample volume first of all, poses serious error in the calibration, since the secondary beam to the input slit has different entrance angle to the analyzer. In JIPP T-IIU in most cases the secondary beam from the upper sample volume hit the upper part of the horizontal port and causes no problem.

The reaction of the multiple process on ND is also observed in Fig. 1. The ND curves at higher gas pressure tend to go down and this fact may be explained by the equivalent shift to lower poloidal sweep voltage i.e., to the lower ND value since in this case lower ND is obtained at lower poloidal voltage.

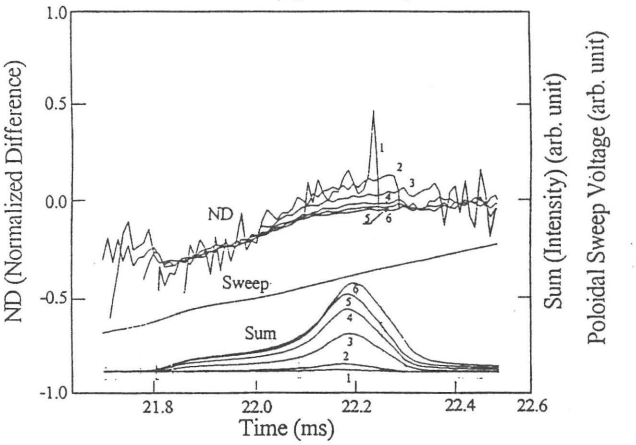

Fig. 1. Behaviours of the detector sum signal and difference of upper and lower detector currents normalized by the sum (ND) under several (1 to 6) successive poloidal sweeps during gas puffing.

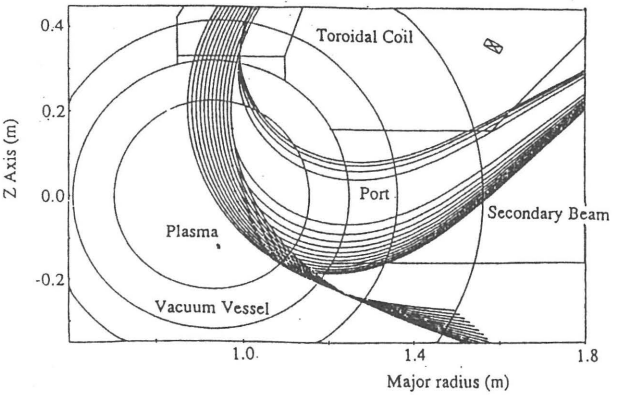

Fig. 2. The position of sample volumes, and the trajectories of primary and secondary beams discussed Tl beam energy is 400 keV. Toroidal field is 3 Tesla.